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(54) Process for producing micromechanical sensors having overload protection

(57) A process is presented for producing micro-mechanical sensors, in particular acceleration sensors, having overload protection. The sensor has at least one paddle having at least one seismic mass 31, and a frame 10 surrounding the at least one paddle. The overload protection consists of fingers or beams 301 which, starting from the surface of the paddle, project into recesses of the frame, and/or of fingers or beams 302 which, starting from the surface of the frame, project into recesses in the surface of the paddle. The structure of the frame and the paddle is developed from a monocrystalline silicon wafer by means of dry-etching processes and/or wet-chemical etching processes, to be precise by means of a structured trench process in conjunction with an undercutting.

FIG. 3

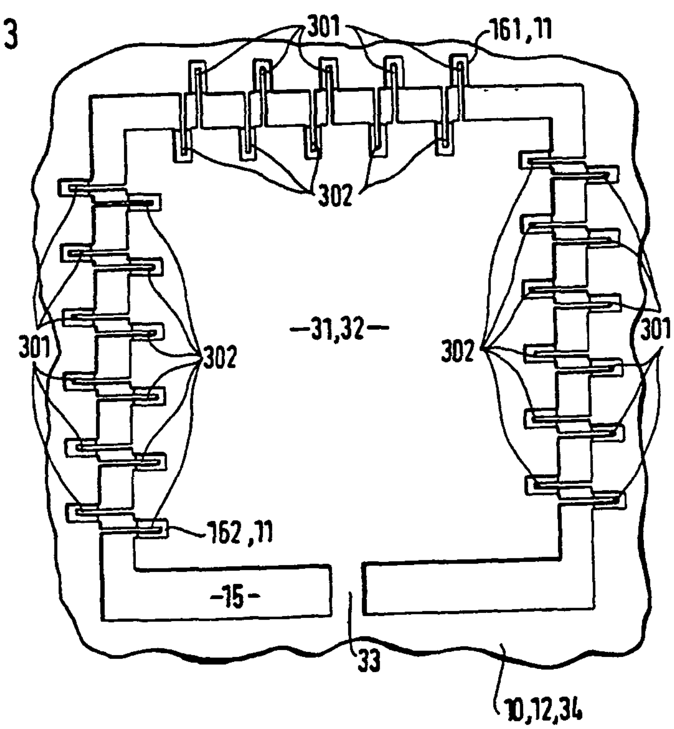

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FIG. 1a

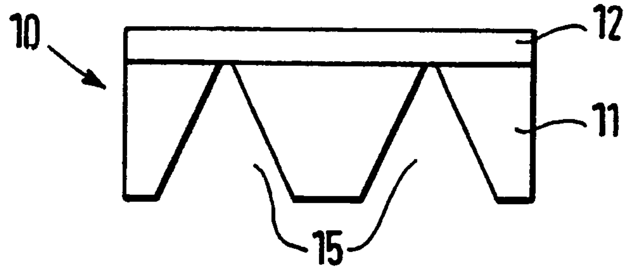


FIG. 1b

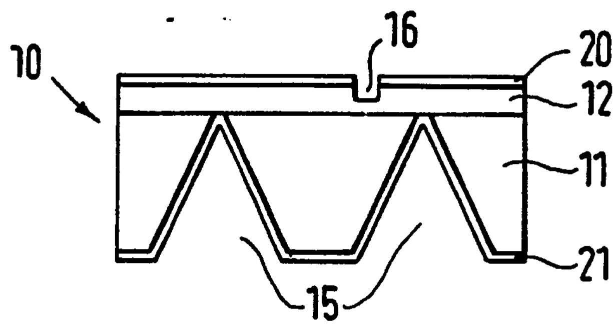


FIG. 1c

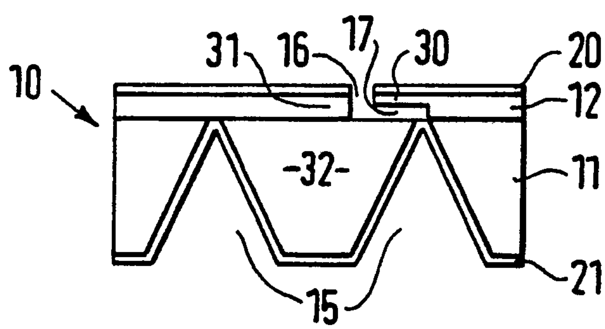


FIG. 1d

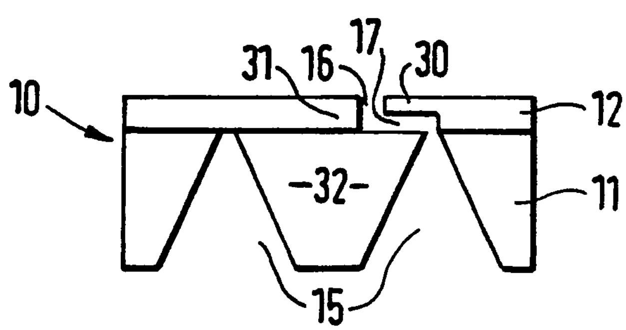


FIG. 2a

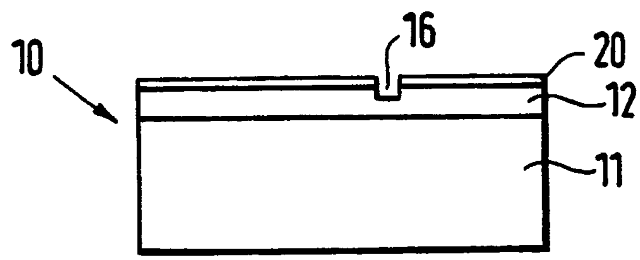


FIG. 2b

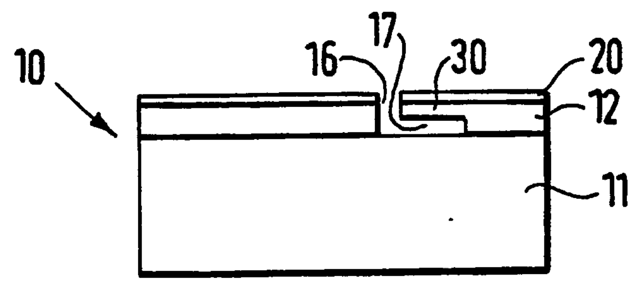


FIG. 2c

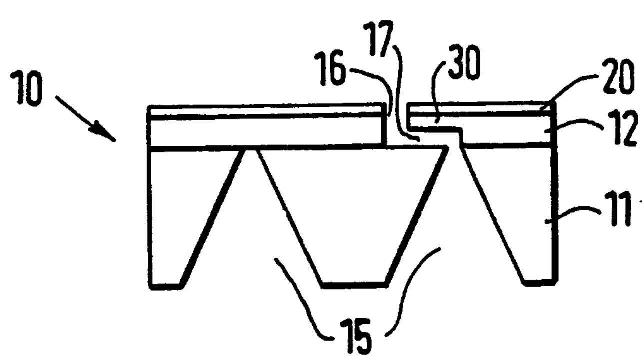
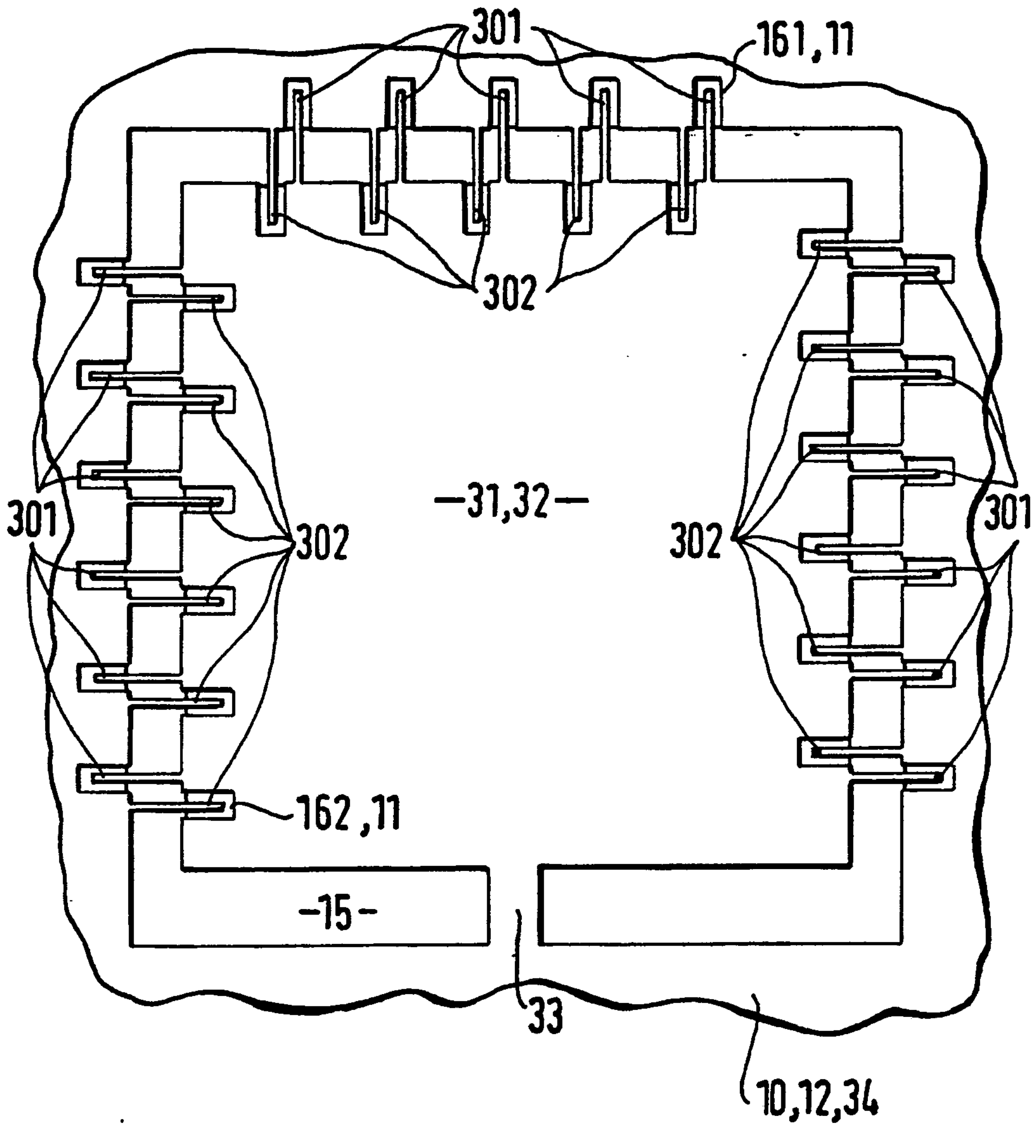


FIG. 3



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Process for producing micromechanical sensors having overload protection

Prior Art

The invention proceeds from a process for producing micromechanical sensors having overload protection according to the generic concept of the main claim.

The Patent Application P 4,000,496, which is not a prior publication, discloses that structures can be etched in semiconductor wafers with the aid of photomasking technology in conjunction with chemical etching processes. In particular, fingers or beams can be exposed by the isotropic wet-chemical undercutting of webs.

"Nova Sensor News", September 1988, number 2, page 3, discloses an acceleration sensor which consists of two structured silicon wafers that are bonded to one another. The structure of an acceleration sensor in the form of a paddle that has a seismic mass and can be deflected perpendicular to the wafer surface is developed from one silicon wafer. The second wafer, which is bonded to the paddle has finger-shaped deflection limiters which project into recesses of the frame surrounding the paddle, as a result of which too strong a deflection in one direction is avoided. Too strong a deflection in the other direction is prevented by the finger-shaped deflection limiters of the second silicon wafer, which project from the frame into recesses of the paddle. The production of such a sensor requires, firstly, the structuring of two silicon wafers and, secondly, a

bonding process which runs at high temperatures and/or high electrical field str ngths. It is therefore not sensible to apply this process to silicon wafers on which circuits have already been integrated.

Advantages of the invention

The process according to the invention having the characterising features of the main claim has, by contrast, the advantage that the acceleration sensor and the overload protection can be structured from one wafer. There is no need for an expensive interconnection technology. A particular advantage is to be seen in that the process can be applied in conjunction with an IC production process, and a further integration, for example with an evaluation circuit, is possible. It is also advantageous that sensor balancing is possible in the mounted state. Furthermore, the process according to the invention advantageously enables the damping of the sensor to be adjusted purposely by means of a suitable geometry of the overload stops.

Advantageous developments of the process specified in the main claim are possible by means of the measures set forth in the subclaims. It proved to be advantageous to structure the silicon wafer starting from the backside and front side. It is particularly advantageous to use silicon wafers which to use from (sic) a p-doped or n-doped substrate and an etch resist layer, which is applied or diffused thereon and has a different doping from the substrate, since the doping transition occurring in this process between the substrate and etch resist layer can advantageously be used as etch resist. A pn-junction biased in the reverse direction, or the junction between the substrate and a p^+-doped epitaxial layer is particularly favourable. It is advantageous to use a trench process for structuring the front side of the silicon waf r, since in this way a good aspect ratio is achi v d in conjunction with very small lateral dimensions of th tr nch s. It is favourable if the recesses

produced in this process do not completely penetrate the etch resist layer, since in this case the lateral undercut, which exposes the finger that serves as the overload protection, is advantageously etched inside the etch resist layer isotropically or anisotropically in a wet-chemical fashion. The front side and the backside of the silicon wafer can advantageously be masked and passivated by means of a low-temperature oxide layer. A particular advantage of the process according to the invention is that overload protections of different shape can be combined into one layout. It is advantageous to realise the protection against an overload by the interaction of many stops in the shape of fingers or beams.

Drawing

Exemplary embodiments of the invention are represented in the drawing and explained in more detail in the following description.

Figures 1a to 1d show the section through a semiconductor structure in the process of production with regard to various processor steps, Figures 2a to 2c show the section through a further semiconductor structure in the process of production, and Figure 3 shows the top view on a sensor.

Description of the invention

Denoted by 10 in Figure 1 is a silicon wafer consisting of a p-substrate 11 and an n-epitaxial layer 12 applied thereto as etch resist layer, which is represented in various stages of the production process of a sensor. In a first process step, the backside of the wafer 10 is structured and purposely anisotropically etched up to the pn-junction. The pn-junction between the epitaxial lay r 12 and the substrate 11, which is conn cted in the reverse direction, serves in this arrangement as tch r sist. Denoted by 15 in Figure 1a is a frame-shap d etched trench, which has been produced

during the tching of th backside. The structured backside of the wafer 10 is subsequently passivated by means of a masking layer 21, low-temperature oxide layers or plasma nitrite layers are preferably used for the passivation. The use of low-temperature layers as passivating layers enables the process to be used on silicon wafers which have already traversed an IC production process. The front side of the wafer 10 is provided with a trench masking 20, and structured in a subsequent trench process. The trenching proved to be particularly advantageous, since it allows a good aspect ratio to be achieved in conjunction with very low lateral dimensions of the trench structure. Represented in Figure 1b is a U-shaped recess 16 produced in such a way, the depth of which is smaller than the thickness of the epitaxial layer. The position of the recess 16 with respect to the etched trench is chosen such that in a subsequent etching step a finger 30 is produced by means of lateral undercutting 17 of the recess 16 inside the layer 12. In accordance with Patent Application P 4,000,496, which is not a prior application, this can be performed anisotropically or isotropically in a wet-chemical fashion, it being necessary to dimension the width of the finger 30 correspondingly. Moreover, the position of the recess 16 and the finger 30, and the magnitude of the undercut 17 are to be chosen such that the undercut 17 abuts the etched trench 15. As a result, a paddle 31 having a seismic mass 32 is produced. This stage of production is shown in Figure 1c before the concluding wet-chemical removal of the masking layers 20 and 21. The removal of the masking layers 20 and 21 is designed to prevent the sensor structure from being unnecessarily strained. Figure 1d shows the finished structured sensor element.

By contrast with the process represented in Figure 1, in which the silicon wafer 10 is firstly structur d starting from the backside, a process is r pr sent d in Figure 2 which likewise leads to the sensor lement represent d in Figure 1d, but in which in a first process step th front side of the silicon

wafer 10, which is provided with a trench masking 20, is structur d in a trench process. Denoted by 16 in Figure 2a is a U-shaped recess produced in the process, which does not completely penetrate the epitaxial layer 12. Subsequently, a lateral undercut 17 is introduced into the epitaxial layer 12 of the wafer 10 by wet-chemical anisotropic or isotropic etching of the recess 16. A finger exposed as a result inside the epitaxial layer 12 is denoted by 30 in Figure 2b. Following the etching of the front side, the etching of the backside is performed, during which process a frame-shaped etched trench denoted by 15 in Figure 2c is introduced into the substrate 11 of the silicon wafer 10. The etched trench 15 is etched up to the pn-junction, biased in the reverse direction as etch resist, between the epitaxial layer 12 and the substrate 11, its length being chosen with respect to the structured front side of the silicon wafer 10 such that, on one side, the etched trench 15 abuts the undercut 17. After removal of the trench masking 20 of the front side, the sensor structure represented in Figure 1d is once again obtained. The passivation of the structured backside is eliminated in this process.

Represented in Figure 3 is the top view on a sensor element whose structure has been developed from a silicon wafer 10. Said element has a paddle 31 having a seismic mass 32, which is connected via a paddle web 33 to a frame 34. Situated between the paddle 31 and the frame 34 is an etched trench 15, which completely penetrates the silicon wafer. The paddle 31 has fingers 301, which are constructed only in the epitaxial layer 12 and project over the etched trench 15 into recesses 161 of the epitaxial layer 12 of the frame. They prevent the paddle 31 from being deflected too far downwards. Fingers 302, which proceed from the frame 34, are likewise constructed only in the epitaxial layer 12 and project over the tched trench 15 into r cesses 162 of the epitaxial layer 12 of the paddle, prevent the paddle 31 from being deflect d too far upwards. The stability of the fing r-shap d stops against overloading is based, on

the one hand, on their shape, but it is essentially realised by means of the interaction of many stops.

Claims

1. Process for producing micromechanical sensors having overload protection, in particular acceleration sensors, which have at least one paddle having at least one seismic mass, a frame surrounding the at least one paddle and an overload protection in the form of fingers or beams, in which the structure of the at least one paddle having the at least one seismic mass, and of the frame are developed from a monocrystalline silicon wafer by means of dry-etching processes and/or wet-chemical etching processes, characterised in that the overload protection (30) is integrated into the structure of the frame (34) and/or of the at least one paddle (31) by means of a structured trench process in conjunction with an undercutting.

2. Process according to Claim 1, characterised in that the structuring of the silicon wafer (10) is performed starting from the front side of the wafer and from the backside of the wafer, and in that a doping transition that occurs between two layers (11, 12) of the silicon wafer (10) serves as etch resist for the etching of the backside and the lateral undercut, one layer being a p-doped or n-doped substrate (11), and the second layer being an etch resist layer (12), which is applied or diffused thereon and has a different doping from the substrate (11).

3. Process according to Claim 1 or 2, characterised in that the front side of the silicon wafer (10) is mask d, pref rably by means of a structured low-temperature oxide layer (20), in that the definition of

th front sid is performed by means of a trench process, and in that at least one rec ss (16) produced in this process does not completely penetrate the etch resist layer (12).

4. Process according to one of the preceding claims, characterised in that the overload protection is exposed in the form of at least one finger (30) by a lateral undercut (17) inside the etch resist layer (12).

5. Process according to one of the preceding claims, characterised in that the backside of the silicon wafer (10) is structured with the aid of photomasking technology, in that the etching of the backside is performed anisotropically in an electrochemical fashion, and in that at least one etched trench (15) is etched up to the doping transition between the substrate (11) and the etch resist layer (12) starting from the backside of the silicon wafer (10).

6. Process according to one of the preceding claims, characterised in that the structured backside of the silicon wafer (10) is passivated, preferably by means of a low-temperature oxide layer (21), when the etching of the backside is performed before the etching of the front side of the silicon wafer (10).

7. Process according to one of the preceding claims, characterised in that the undercut (17) is etched so far that it merges with the at least one etched trench (15).

8. Process according to one of the preceding claims, characterised in that the masking layers (20, 21) are removed after the etching in a wet-chemical fashion.

9. Sensor having overload protection, in particular for the measurement of acceleration, according to a process according to one of Claims 1 to 8, characterised in that there is constructed in the etch resist layer (12) of the paddle (31) at least one finger (301) which projects into at least one recess (161) of the etch resist lay r (12) of the frame (34).

10. Sensor having overload prot ction, in particular for th measurement of acceleration, according to a process according to on of Claims 1 to 8, characterised

in that there is constructed in the etch resist layer (12) of the frame (34) at least one finger (302) which projects into at least one recess (162) of the etch resist layer (12) of the paddle (31).

11. A process for producing a micromechanical sensor substantially as herein described with reference to the accompanying drawings.

12. A sensor produced from the process as claimed in any of the preceding claims.

13. A sensor substantially as herein described with reference to the accompanying drawings.

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